

A proposal for K and C-band simultaneous dual-band observing systems

Aletha de Witt
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Astronomy Observatory

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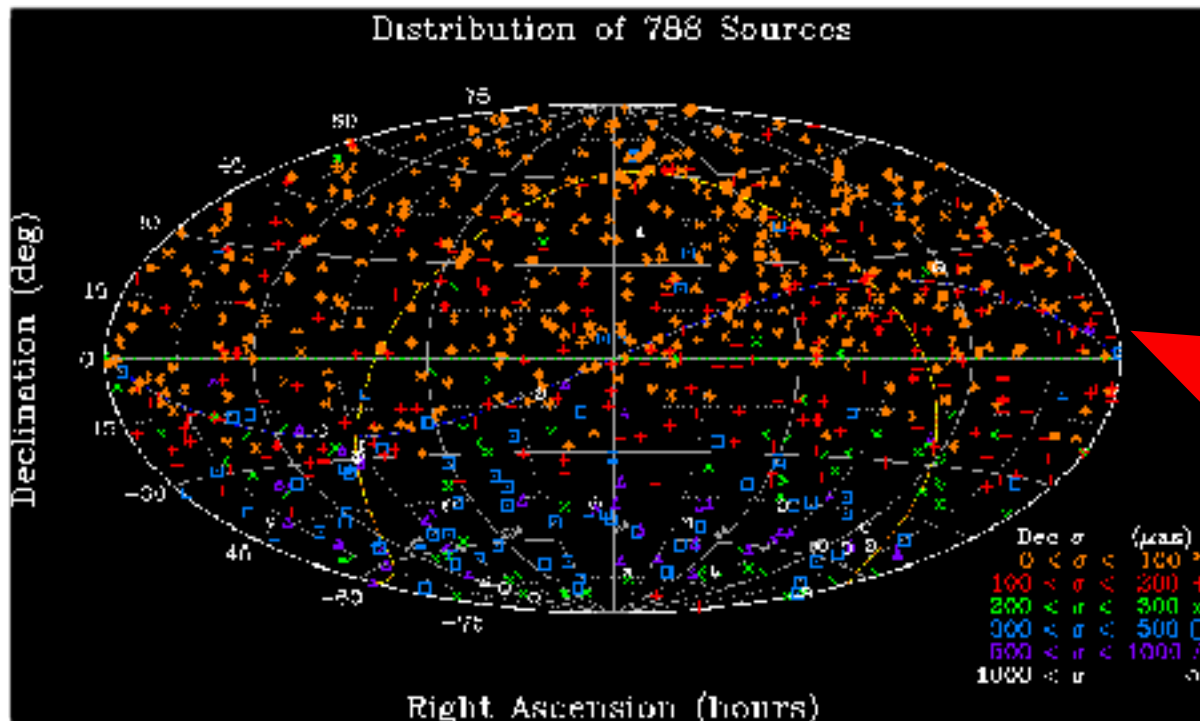
Overview: C/K-band system

- **A dual-band system at either X/K (8.4/24 GHz) or C/K (6.7/24 GHz) would be very useful for future K-band CRF work.**
- The K-band (24 GHz) CRF has already surpassed ICRF2 in precision and is on course to catch the current S/X CRF precision. ([e.g. de Witt et al., EVGA, 2017](#))
- Proper ionospheric calibrations for K-band CRF may become a limiting error in the near future and dual-band observations will be needed to solve this problem.
- A C/K system would be more useful to the larger astronomy community and it is more sensitive than the X-band receiver.
- We propose a C/K dichroic system for legacy antennas as this will be the most cost-effective and easiest to implement.
- We also believe that there is a solution for broadband receivers to scale up to higher radio frequencies in future, to avoid RFI problems in the lower frequency bands.

Astro-geo motivation: ionospheric calibration

Simultaneous observations at two well separated bands have long been a standard for calibrating the ionosphere:

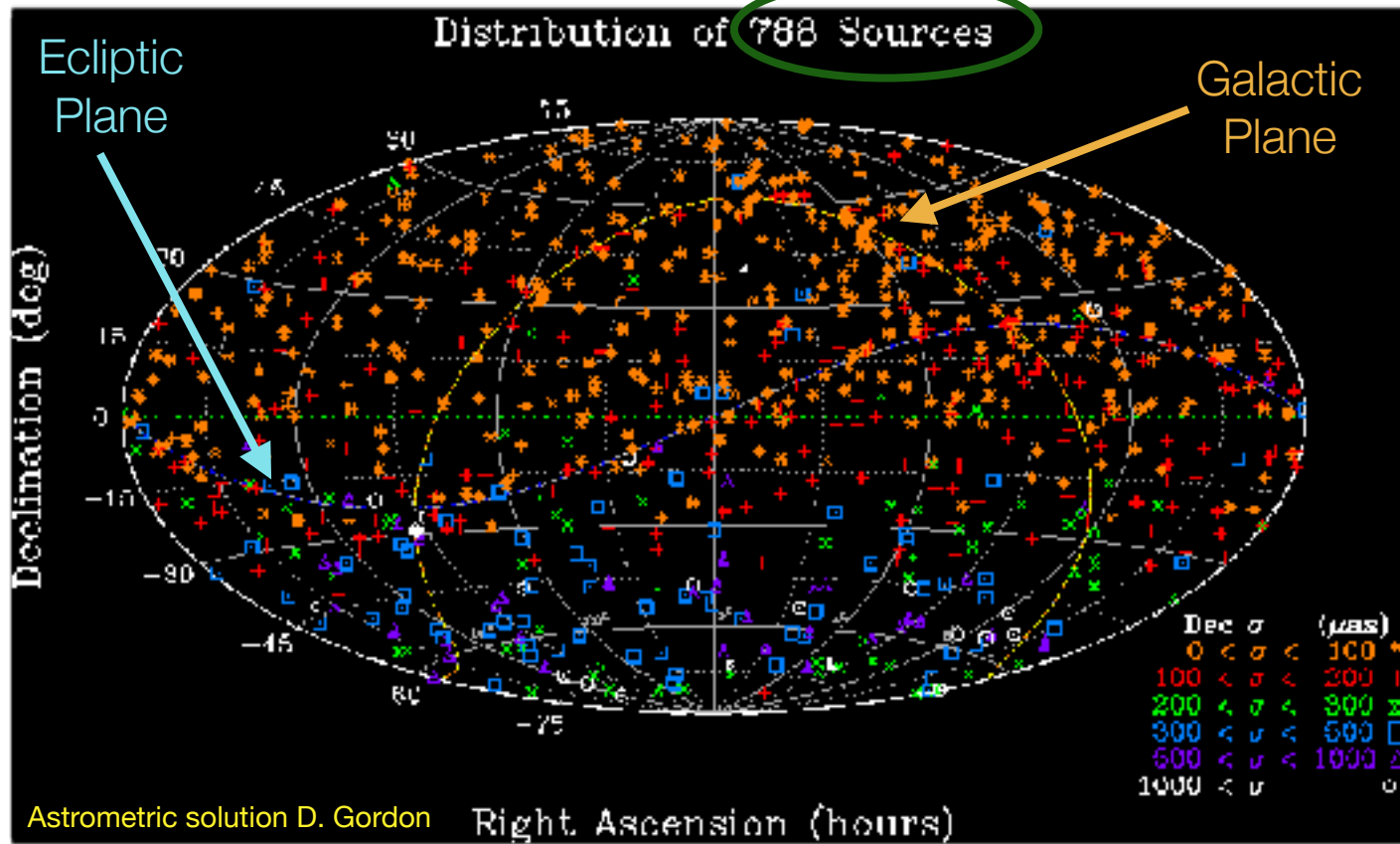
- S/X (2.3, 8.4 GHz) work has been ongoing since 1978 (e.g. Ma et al., ICRF2, 2009)
S-band has been steadily deteriorating due to RFI
- X/Ka (8.4, 32 GHz) work since 2005 (e.g. Jacobs et al., EVGA, 2015)
Ka-band typically available only at spacecraft tracking sites.



We propose developing systems for simultaneous C/K-band observations to solve the ionosphere problem.

From the numerous K-band equipped observatories, there already exists about 0.25 million observations from single-band K-band systems.

Astro-geo motivation: ionospheric calibration



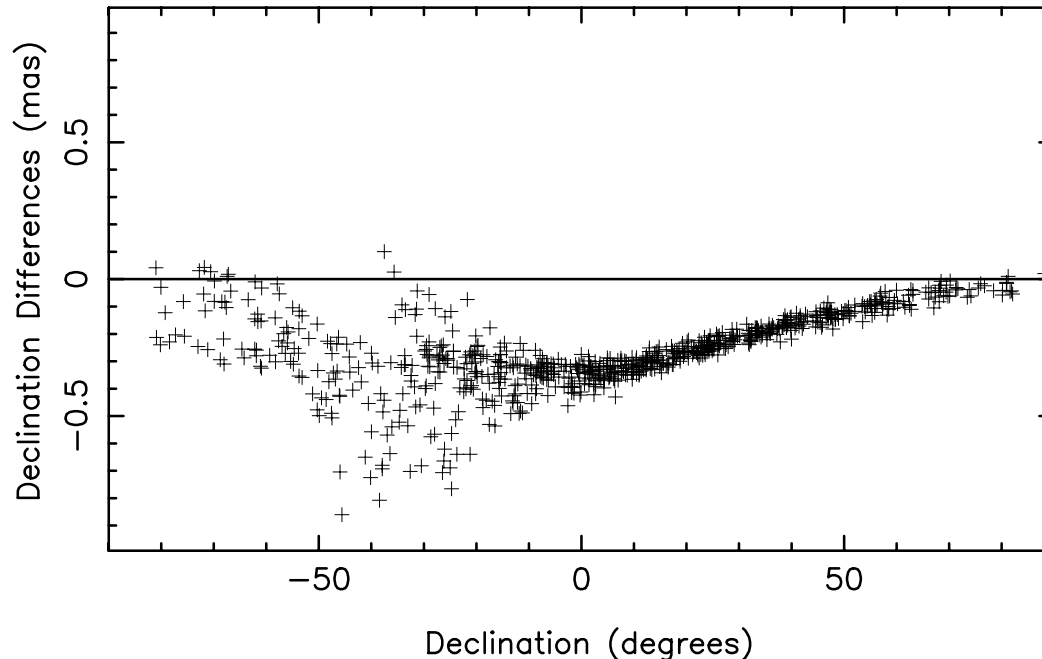
K-band CRF-17.10.04

12 x VLBA (Lanyi et al. 2010)
3 x Galactic plane (Petrov)
8 x Hart-Hob (2 Gbps)
12 x VLBA (2 Gbps)

- K-band CRF has already surpassed ICRF2 in precision (de Witt et al., EVGA, 2017)
- Projected K-band precision mid-2018, comparable to current SX frame (de Witt et al., EVGA, 2017)
- K-band frame have lower % outliers, smaller scatter vs Gaia (Jacobs et al., Gaia IAU Symp 330, 2017)
- **Looking at systematics, proper ionospheric calibrations may become a limiting error in the near future => a dual-band system would be very useful for future K-band CRF work (e.g. ICRF4) !!**

Astro-geo motivation: ionospheric calibration

K-band (GPS Iono) - (No Iono)



Currently we calibrate ionosphere with GPS:

2.5x5 deg spatial resolution
2 hour temporal resolution

The effect on K-band CRF with no ionospheric calibration:

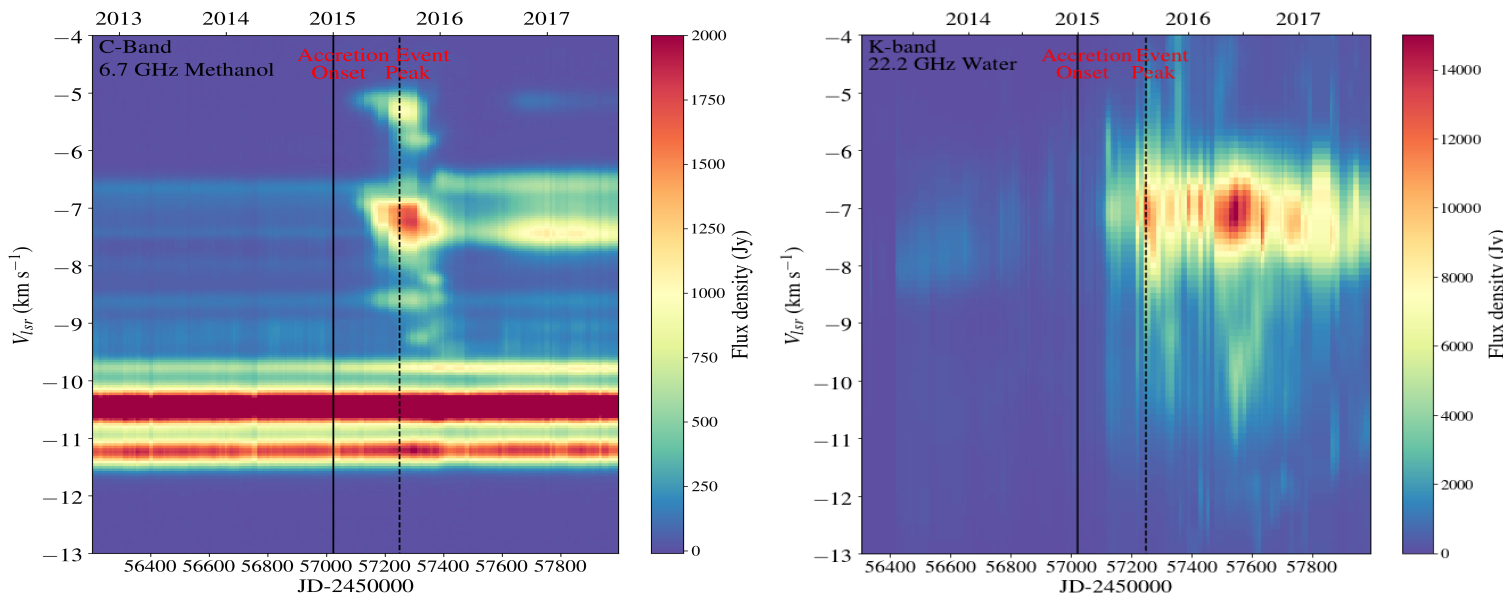
~400 μ as in the far south at Dec = -40°
gets smaller going both north and south

- Our goal with the K-band celestial frame is to get down to the structure floor for the competing S/X frame which is about 20 μ as.
- That means we need ionospheric calibrations good to about 5%
- A dual C/K system would remove any variations on scales finer than these numbers.

Astronomy motivation

Simultaneity means fewer observations for the same number of photons collected !

- Big advantage for single-dish monitoring observations (spectroscopy and continuum).
- With a C/K dual-band system 6.7 GHz methanol and 22 GHz water masers can be observed simultaneously.



Dynamic spectra of 6.7 GHz methanol and 22.2 GHz water masers associated with NGC6334F in the Cat's Paw Nebula.

Accretion event in 2 of the 10 transitions it flared simultaneously in.

- Takes 10 to 15 days to observe each transition individually.
- Simultaneity means we can look for more sources and directly compare transitions.

(G. MacLeod, HartRAO)

Proposal for C/K dual-band capability



- **Given budget realities we propose a C/K dichroic system for legacy antennas.**
- A dual-band system at C/K would be very useful for future K-band CRF work (e.g. ICRF4).
- A C/K system would allow direct line of site calibrations using the ideal 1:4 ratio of frequencies (6:24 GHz) and more spatial and temporal resolution to be better than GPS.
- A C/K system would be more useful to the larger astronomy community and it is more sensitive than the X-band receiver.

Advantages of a dichroic system:

Many observatories already have separate C- and K-band receivers

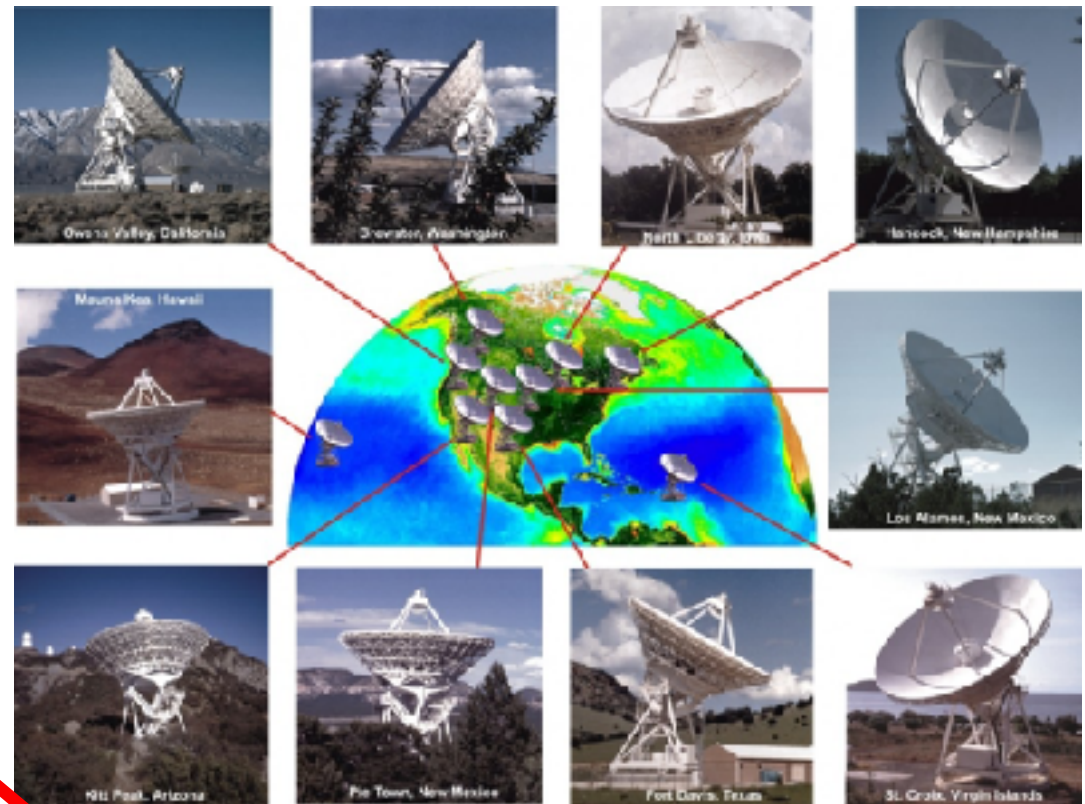
Would only need a dichroic and some re-arrangement of receiver positioning

No receiver development would be needed.

VLBA Proposed Plans

Proposed future upgrade on the Very Long Baseline Array (VLBA):

- Dual-band X/K or C/K dichroic system.
- To anticipate astrometric performance of such a system we will propose frequency switching observations via the USNO VLBA allocation, for near-simultaneous observations.
- Such observations will build on the published work investigating the performance of these frequency pairs for astrometry and geodesy ([Lanyi et al, AJ, 2010](#)).

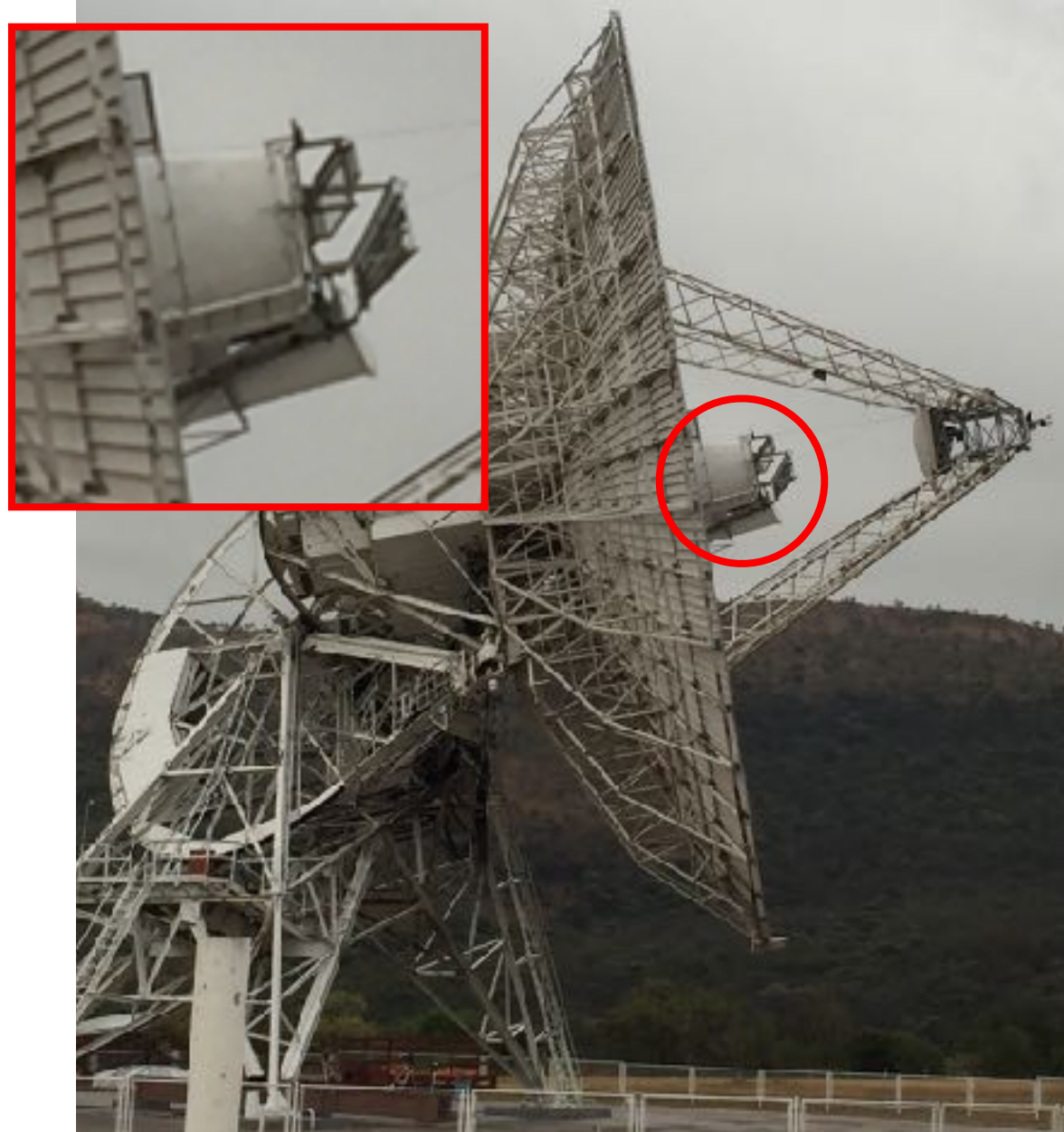


Will request two 24-hour sessions at 2Gbps. One using X-K-X (or K-X-K) and another using C-K-C (or K-C-K),

Proposed plans in the South

Proposed future upgrade on the HartRAO 26m telescope:

- In-house design of a simple C/K dichroic system for HartRAO 26m.
- A scaled down version ($\sim 1/3$) of the current S/X dichroic reflectors should not be particularly difficult to implement
(private communication, G. Nickolson, HartRAO, Sept 2017).
- Prototype will be tested on the ground to demonstrate proof of concept (a student project?).
- Final design will be bolted onto the top of the cone.



Proposed plans in the South

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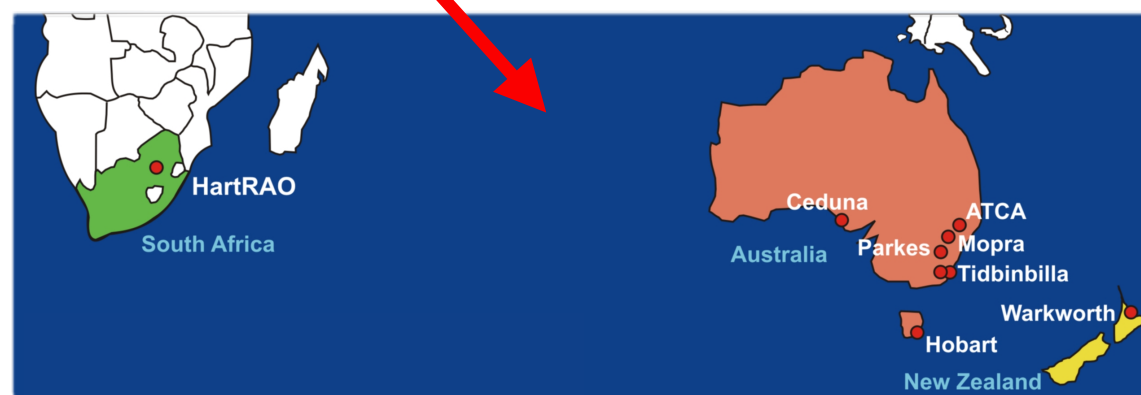
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- Final design will be bolted onto the top of the cone.



Proposed plans in the South

Proposed future upgrade for Southern K-band CRF:

- The dichroic works well with Cassegrain systems like the HartRAO 26m.
- Hobart 26m would be best served with a concentric system such as the current S/X system, but a dichroic is not out of the question.
- K-band to be tested on the Warkworth 30m in the near future (talk by).
- A dual system would also be to their advantage for single-dish monitoring observations.



A broadband C- to K-band concept



- A broadband C - K system might be a logical extension of the current broadband concept. RFI may be a driver for VGOS broadband to be scaled to higher frequencies — VGOS 2.0.

- **Quadridge feeds:**

Feeds covering C/K (4 to 24 GHz) or C/Ka (5.3 to 32 GHz) are feasible by scaling the 8-48 GHz design ([private communication, Jose Velazco, JPL, Sept. 2017](#))

Next step is a lab demo !!

- **Should we scale 4-24 or 5-32 ?**
 - ➔ 4 GHz is closer to current VGOS 1.0 spectrums.
 - ➔ 32 GHz provide compatibility with the large DSN antennas of NASA (34m), ESA (35m) and JAXA (54m).
 - ➔ 32 GHz could provide capability to WVR monitoring to remove the effect of clouds

Summary: C/K-band system

- **Goal:** To develop C- and K-band simultaneous dual-band observing systems to get direct line of sight ionospheric calibration for astro-geo observations.
- **Roadmap:**
 1. **Legacy antennas:** Design C/K dichroic system for HartRAO 26m antenna
 2. **Legacy antennas:** Design C/K or X/K dichroic system for the VLBA antennas
 3. To scale up VGOS broadband to avoid RFI

A comic book illustration featuring Superman in the foreground, wearing his iconic blue suit with a red and yellow 'S' emblem, a white shirt, and a red tie. He is holding a pair of black-rimmed glasses in his right hand. In the background, Lois Lane is visible, looking towards him. A speech bubble originates from Lois, containing the text 'C/K System.... Clark Kent? A SUPER receiver !!'.

C/K System.... Clark Kent?
A SUPER receiver !!

Thank you !

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